POSSIBILITIES TO ESTABLISH BIOGAS PLANTS IN THE NORTHERN GREAT PLAIN REGION, BASED ON CATTLE AND PIG MANURE*

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Abstract

In order to estimate the biogas potential of the Northern Great Plain region, biogas quantity producible from the manure of cattle and pig livestock was investigated, and the possible plant sizes based on that. Manure production of the settlements was calculated with the Zutavern-formula. From the producible gas quantities, possible plant sizes were defined, with lower limits of 500, 300 and 100 kW_{el}. Typical specific and aggregate indicators of the potential plants were defined: total electric power (MW_{el}), minimum and average plant size (kWl_{el}), number and share of settlements that can be involved into biogas production, and achievable biogas potential exploitation. In the region, near 70% potential utilization can be reached with the establishment of biogas plants having a minimum size of 100 kW_{el}. Construction of plants with more than 300 kW_{el} power is possible in Jász-Nagykun-Szolnok and Hajdú-Bihar counties, and with more than 500 kW_{el} power in Hajdú-Bihar county.

Keywords

biogas, plant size, bio-waste, renewable energy, manure management

1. Objective

In the new program of the Hungarian biomass energy development, biogas potential of the Northern Great Plain region was investigated (1.2.3. subtopic). From animal manures, cattle and pig manure are most suitable for the wet process that is the most widespread method in Europe [3], thus, biogas quantity producible from these was investigated, and the plant sizes reachable based on these input materials. To define plant sizes, three lower limits concerning economy of scale were used, as of 500, 300 and 100 kW_{el} electric power. Data were analyzed based on the principle of distributed power generation [6], examining the number of settlements involved, and total and average installed power output. In a system of local power generation, logistic costs of animal manures, which have low energy content and market value, can be minimzed.

Large-scale biogas production system, it is not without example in Europe; centralized biogas plants in Denmark codigest mainly manure, together with other organic waste such as industrial organic waste, source sorted household waste, and sewage sludge. In 2001, the 22 large-scale centralized biogas plants treated approx 1.2 million tons of manure as well as approx. 300,000 tons of organic industrial waste. Besides the centralized biogas plants there are a large number of smaller farm scale plants. The long-term energy plan objective is a 10-fold increase of the 1998 level of biogas production by the year 2020. This helps to achieve a target of 12–14% of the national energy consumption being provided by renewable energy by the year 2005 and 33% by the year 2030. A major part of this increase is expected to come from new centralized biogas plants [2].

In Hungary, the system of the biogas plants is not yet set. However, the fact can be foreseen, that competitive technology for biomass production and utilization for energy purposes cannot be elaborated without the cooperation of the scientific disciplines involved. The agricultural engineering has a significant role in such cooperation [7].

2. Methods and materials

Based on the methods elaborated in the previous years, our investigations were extended to the other two counties of the Northern Great Plain region. Based on the figures of biogas potential on the different settlements, biogas plant scale was examined with 500, 300 and 100 kW_{el} minimum size limits, in order to find out the reachable plant sizes on the settlements of Hajdú-Bihar, Jász-Nagykun-Szolnok and Szabolcs-Szatmár-Bereg counties. Typical specific and aggregate indicators of the potential plants were defined: total electric power (MW_{el}), minimum and average plant size (kW_{el}), number and share of settlements that can be involved into biogas production, and achievable biogas potential exploitation.

Determination of livestock

Based on the General Agricultural Census (ÁMÖ 2000), the ratio of the different species on the settlements can be calculated from the data of the year 2000. These ratios multiplied with the county-level statistical data from 2005 (in this year, the aggregate livestock of the two species had a minimum within the past ten years) result in the livestock population of the species on the settlements (Table 1).

Table 1. Cattle and pig livestock in the Northern Great Plain region (2005)

Area	Cattle		Pig		Total
	1000	1000	1000	1000	1000
	head	LU	head	LU	LU
Hajdú-Bihar county	83	66.4	443	50.5	116.9
Jász-Nagykun-Szolnok county	52	41.6	259	29.5	71.1
Szabolcs-Szatmár-Bereg county	33	26.4	220	25.1	51.5
Northern Great Plain region	168	134.4	922	105.1	239.5

Notes: LU=Livestock Unit. 1 average cattle = 0.8 LU, 1 average pig = 0.114 LU

Manure production and biogas potential of cattle and pig

In order to estimate the quantity of manure produced on the settlements, livestock extents of the different species should be converted into livestock unit. Calculation of manure quantity can be performed with the help of the Zutavern-formula:

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$$\text{Yearly manure production} = \{(\text{livestock unit [head]} \times 1.46[\text{t/db}]) + (\text{straw bedding [t]} \times 0.6)\} \times 4(3) \quad (1)$$

Amount of straw bedding is the following: cattle: 1 t/livestock unit, pig: 1.4 t/livestock unit.

To calculate the manure's biogas yield, coefficients from the literature were used. Gas production figures are 225 m^3/t organic dry matter from cattle manure and 445 from pig manure [4]. For the calculations, cattle manure was considered with 29% dry matter and 24% organic dry matter content [1], whereas the same values for pig slurry were 4.5% and 3.7% [5]. The resulting biogas quantities of the settlements were converted into energy values (with 60% CH_4-share and 22 MJ/m^3 energy content).

Energy values received from biogas potential calculations were used to calculate plant size with the help of the coefficients of the gas engine power generation. In the course of energy to output calculations, yearly 8000 hours of operation (91.3% capacity utilization or availability) and 35%-os electric efficiency were considered, plant size was obtained in electric power output (kW_{el}). The plant sizes for the different settlements were then filtered with Excel functions, describing the settlements which were above the 500, 300 and 100 kW_{el} thresholds. From the resulting table, characteristic indicators were specified for the biogas plants that can be established in Hajdú-Bihar county. These are: total power output, average plant size, number and share of settlements that can be involved in biogas production. These indicators were calculated also for the four size classes created with the category limits (Table 2), and for the (cumulative) groups fulfilling the size criteria of these classes.

3. Results and discussion

Cattle- and pig manure produced in the Northern Great Plain region amounts to ca. 2 million tons, whereby the minimum value is 20 tons, the maximum value is around 120 thousand tons. Regarding livestock size and manure production, the poorest county is Szabolcs-Szatmár, the best county is Hajdú-Bihar. Biogas producible form this manure reaches altogether 76 million m^3.

Out of the given biogas potential, possible plant size reaches ca. 1100 kW_{el} on one settlement, and in average, ca. 53 kW_{el} within the region. The upper size class contains 5 settlements from the region, the middle size class contains 13 settlements, and with the 100 kW_{el} lower power output limit, biogas plants with a 14 MW_{el} total power can be einstalled on 53 settlements.

Table 2 summarizes the results of the calculations.

4. Conclusions

In the Northern Great Plain region, the settlements' biogas potential using cattle and pig manure, in case of installation of plants with 100 kW_{el} minimum size helps to an almost 70% biogas potential utilization. In Jász-Nagykun-Szolnok county, also plants with more than

300 kW_{el} power can be established. In Hajdú-Bihar county, even plants with more than 500 kW_{el} can be installed. The sporadic and small-sized livestock in Szabolcs-Szatmár-Bereg county make difficult to reach economic plant size, over 100 kW_{el} nine settlements (4% of the settlements) can establish biogas plants. In Jász-Nagykun-Szolnok county, the share of the settlements in the size classes over 100 kW_{el} is 25%; in Hajdú-Bihar county, this share is over 80%.

The remark shall be added that the Zutavern-formula produces lower figures in manure quantity calculations than other coefficients used in our former calculations, thus it gives a lower limit of biogas plants' possibilities. Besides this, pessimistic values were considered even in the case of livestock, too. The real situation looks even better considering that e. g. in Denmark animal manure is utilized in a centralized system. Here the thermophilic bioreactors produce greater gas yields and shorter retention time: the system allows the transport of pig slurry from several (even 10) kilometres into the biogas plant.

In Denmark, the system of centralised plants was created with central planning and with taking into account the multiple advantages of a biogas plant, thus not only on an energy basis. In our opinion, biogas production's system should be investigated with similar economic calculations also in Hungary.

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Table 2. Plant sizes, number of settlements that can be involved in biogas production, and biogas potential utilization in (with no transport)

	Characteristics (sorted by descending lower limits)			
	min. 500 kW	min. 300 kW	min. 100 kW	Without lower limit
Hajdú-Bihar county				
Number of settlements	5	7	25	82
Share of settlements	6.1%	8.5%	30.5%	100.0%
Installable power output, MW_{el}	4.3	5.1	8.1	10.0
Average plant size, kW_{el}	860	720	330	120
Minimum plant size, kW_{el}	630	380	100	0
Biogas potential utilization	43.1%	50.7%	81.5%	100.0%
Jász-Nagykun-Szolnok county				
Number of settlements	0	6	19	77
Share of settlements	0.0%	7.8%	24.7%	100.0%
Installable power output, MW_{el}	0.0	2.1	4.3	6.2
Average plant size, kW_{el}	0	360	220	80
Minimum plant size, kW_{el}	0	310	100	0
Biogas potential utilization	0.0%	34.7%	69.1%	100.0%
Szabolcs-Szatmár-Bereg county				
Number of settlements	0	0	9	228
Share of settlements	0.0%	0.0%	3.9%	100.0%
Installable power output, MW_{el}	0.0	0.0	1.5	4.2
Average plant size, kW_{el}	0	0	160	20
Minimum plant size, kW_{el}	0	0	110	0
Biogas potential utilization	0.0%	0.0%	35.1%	100.0%
Northern Great Plain region				
Number of settlements	5	13	53	387
Share of settlements	1.29%	3.36%	13.70%	100.00%
Installable power output, MW_{el}	4.3	7.2	13.9	20.4
Average plant size, kW_{el}	860	554	262	53
Minimum plant size, kW_{el}	630	310	100	0
Biogas potential utilization	21.08%	35.29%	68.14%	100.00%

Source: own calculations